APPENDIX C

PROCEDURES FOR DETERMINING THE FATIGUE LIFE OF BITUMINOUS CONCRETE

C-1. Laboratory Test Method.

a. General. A laboratory procedure for determining the fatigue life of bituminous concrete paving mixtures containing aggregate with maximum sizes up to 1½ inches is described in this appendix. The fatigue life of a simply supported beam specimen subjected to third-point loadings applied during controlled stress-mode flexural fatigue tests is determined.

b. Definitions. The following symbols are used in the description of this procedure:

(1) ϵ = initial extreme fiber strain (tensile and compressive), inches per inch.

(2) N_f = fatigue life of specimen, number of load repetitions to fracture.

Extreme fiber strain of simply supported beam specimens subjected to third-point loadings, which produces uniaxial bending stresses, is calculated from

$$\epsilon = \frac{12td}{(3L^2 - 4a^2)}$$

where

t = specimen depth, inches
d = dynamic deflection of beam center, inches
L = reaction span length, inches
a = L/3, inches

c. Test equipment.

(1) The repeated flexure apparatus is shown in figure C-l. It accommodates beam specimens 15 inches long with widths and depths not exceeding 3 inches. A 3,000-pound-capacity electrohydraulic testing machine capable of applying repeated tension-compression loads in the form of haversine waves for 0.1-second durations with 0.4-second rest periods is used for flexural fatigue tests. Any dynamic testing machine or pneumatic pressure system with similar loading capabilities is also suitable. Third-point loading, i.e., loads applied at distances of L/3 from the reaction points, produces an approximately constant bending moment over the center 4 inches of a 15-inch-long beam specimen with widths and depths not exceeding 3 inches. A sufficient load, approximately 10 percent of the load deflecting the beam upward, is applied in the opposite direction, forcing the beam to return to its original horizontal position and holding it at that position during the rest period. Adjustable stop nuts installed on the flexure apparatus loading rod present the beam from bending below the initial horizontal position during the rest period.

(2) The dynamic deflection of the beam's center is measured with a Linear Variable Differential Transformer (LVDT). An LVDT that has been found suitable for this purpose is the Sheavitz type 100 M-L. The LVDT core is attached to a nut bonded with epoxy cement to the center of the specimen. Outputs of the LVDT and the electrohydraulic testing machine's load cell, through which loads are applied and controlled, can be fed to any suitable recorder. The repeated flexure apparatus is enclosed in a controlled-temperature cabinet capable of controlling temperatures within ±1/2 degree F. A Missimer's model 100 x 500 carbon dioxide plug-in temperature conditioner has been found to provide suitable temperature control.

d. Specimen preparation. Beam specimens 15 inches long with 3½-inch depths and 3¼-inch widths are prepared according to ASTM D 3202. If there is undue movement of the mixture under the compactor foot during beam compaction, the temperature, foot pressure, and number of tamping blows should be reduced. Similar modifications to compaction procedures should be made if specimens with less density are desired. A diamond-blade masonry saw is used to cut 3-inch or slightly less deep by 3-inch or slightly less wide test specimens from the 15-inch-long beams. Specimens with suitable dimensions can also be cut from pavement samples. The widths and depths of the specimens are measured to the nearest 0.01 inch at the center and at 2 inches from both sides of the center. Mean values are determined and used for subsequent calculations.

e. Test procedures.

(1) Repeated flexure apparatus loading clamps are adjusted to the same level as the reaction clamps. The specimen is clamped in the fixture using a jig to position the centers of the two loading clamps 2 inches

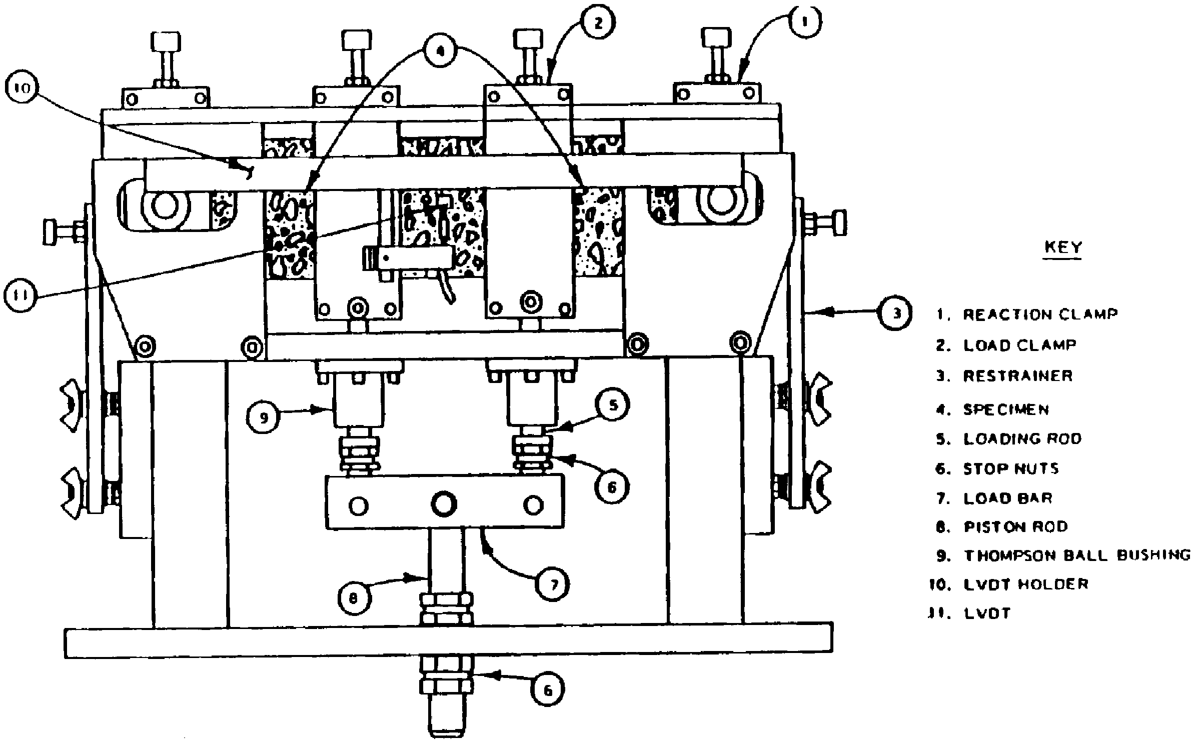

Figure C-1. Repeated Flexure Apparatus.

from the beam center and to position the centers of the two reactions clamps 6½ inches from the beam center. Double layers of Teflon sheets are placed between the specimen and the loading clamps to reduce friction and longitudinal restraint caused by the clamps.

(2) After the beam has reached the desired test temperature, repeated loads are applied. Duration of a load repetition is 0.1 second with 0.4-second rest periods between loads. The applied load should be that which produces an extreme fiber stress level suitable for flexural fatigue tests. For fatigue tests on typical bituminous concrete paving mixtures, the following ranges of extreme fiber stress levels are suggested:

Temperature, degrees F.	Stress Level Range, psi
55	150 to 450
70	75 to 300
85	35 to 200

The beam center point deflection and applied dynamic load are measured immediately after 200 load repetitions for calculation of extreme fiber strain ϵ. The test is continued at the constant stress level until the specimen fractures. The apparatus and procedures described have been found suitable for flexural fatigue tests at temperatures ranging from 40 to 100 degrees F. and for extreme fiber stress levels up to 450 psi. Extreme fiber stress levels for flexural fatigue tests at any temperature should not exceed that which causes specimen fracture before at least 1,000 load repetitions are applied.

(3) A set of 8 to 12 fatigue tests should be run for each temperature to adequately describe the relationship between extreme fiber strain and the number of load repetitions to fracture. The extreme fiber stress should be varied such that the resulting number of load repetitions to fracture ranges from 1,000 to 1,000,000.

f. Report and presentation of results. The report of flexural fatigue test results should include the following:

(1) Density of test specimens.
(2) Number of load repetitions to fracture, N_f.
(3) Specimen temperature.
(4) Extreme fiber stress, σ.

The flexural fatigue relationship is plotted in figure C-2.

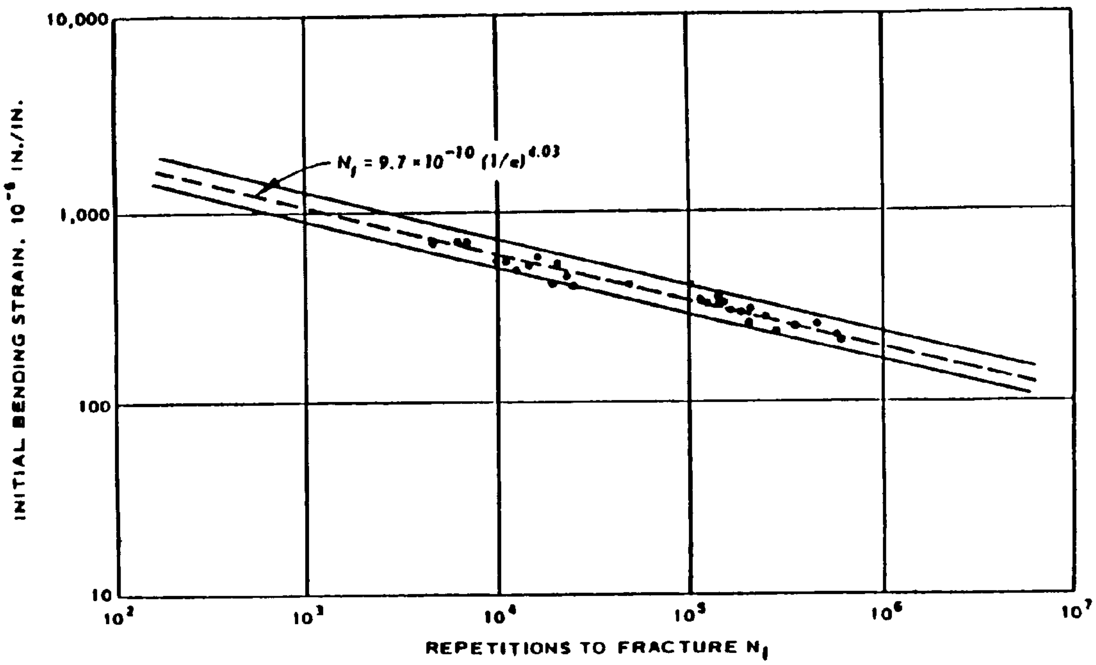

Figure C-2. Initial Mixture Bending Strain Versus Repetitions to Fracture in Controlled Stress Tests.

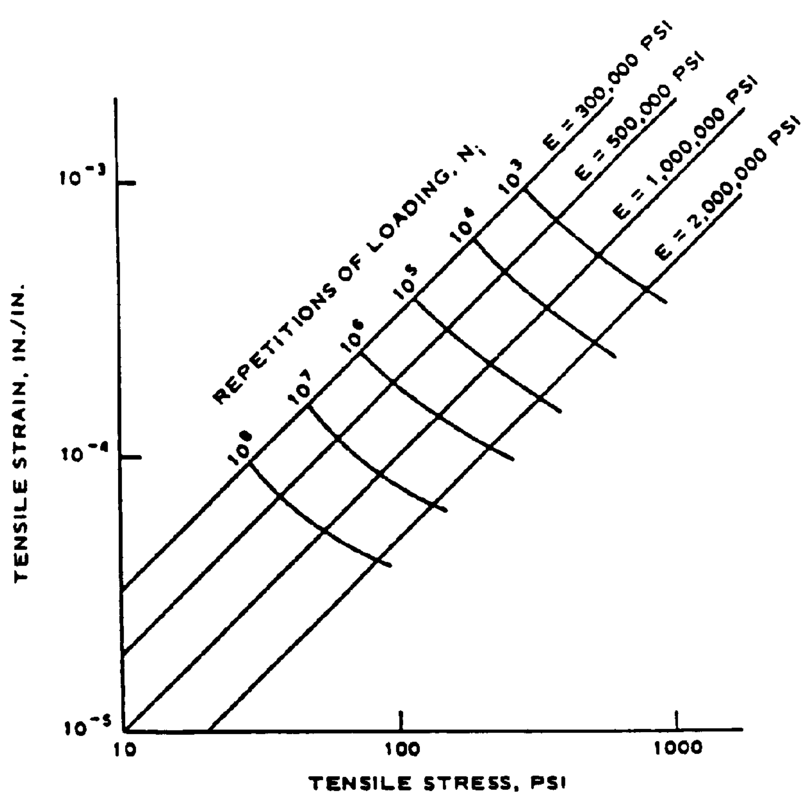

Figure C-3. Provisional Fatigue Data for Bituminous Base Course Materials.

C-2. Provisional Fatigue Data for Bituminous Concrete.

Use of the graph shown in figure C-3 to determine a limiting strain value for bituminous concrete involves first determining a value for the elastic modulus of the bituminous concrete. Using this value and the design pavement service life in terms of load repetitions, the limiting tensile strain in the bituminous concrete can be read from the ordinate of the graph.